WHAT IS CLAIMED IS:

1. A wavefront dividing type optical integrator, having a number of micro lenses arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident luminous flux;

each said micro lens having a rectangular entrance surface and a rectangular exit surface, and satisfying at least one of the following conditions:

$$(d_1/2)(D_1/2)/(\lambda \cdot f) \geq 3.05$$

$$(d_2/2)(D_2/2)/(\lambda \cdot f) \geq 3.05$$

where f is the focal length of each said micro lens, d_1 is the length of one side of the entrance surface of each said micro lens, d_2 is the length of the other side of the entrance surface of each said micro lens, D_1 is the length of the side of exit surface in each said micro lens corresponding to said one side of entrance surface, D_2 is the length of the side of exit surface in each said micro lens corresponding to said other side of entrance surface, and λ is the wavelength of said incident luminous flux.

2. An optical integrator according to claim 1, wherein the length d_1 of said one side of entrance surface is longer than the length d_2 of said other side of entrance surface, and wherein the condition of

$$(d_1/2)(D_1/2)/(\lambda \cdot f) \geq 3.05$$

is satisfied.

3. A wavefront dividing type optical integrator,

having a number of micro lenses arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident luminous flux;

each said micro lens having a rectangular entrance surface and a circular or regular hexagonal exit surface, and satisfying at least one of the following conditions:

$$(d_1/2)(D/2)/(\lambda\cdot f)\geq 3.05$$

$$(d_2/2)(D/2)/(\lambda\cdot f)\geq 3.05$$

where f is the focal length of each said micro lens, d_1 is the length of one side of the entrance surface of each said micro lens, d_2 is the length of the other side of the entrance surface of each said micro lens, D is the diameter of the circular exit surface or the diameter of a circle circumscribing the regular hexagonal exit surface of each said micro lens, and λ is the wavelength of said incident luminous flux.

4. An optical integrator according to claim 3, wherein the length d_1 of said one side of entrance surface is longer than the length d_2 of said other side of entrance surface, and wherein the condition of

$$(d_1/2)(D/2)/(\lambda\cdot f)\geq 3.05$$

is satisfied.

5. A wavefront dividing type optical integrator, having a number of micro lenses arranged two-dimensionally, for forming a number of light sources by dividing a wavefront of an incident luminous flux;

each micro lens having a circular entrance surface with a diameter of d or a regular hexagonal entrance surface inscribed in a circle having a diameter of d, and satisfying the following condition:

$$(d_1/2)^2/(\lambda \cdot f) \geq 3.05$$

where f is the focal length of each said micro lens, and λ is the wavelength of said incident luminous flux.

6. An illumination optical apparatus for illuminating a surface to be irradiated according to a luminous flux from a light source, said illumination optical apparatus comprising:

the optical integrator according to claim 1, disposed in an optical path between said light source and said surface to be irradiated, for forming a number of light sources according to a luminous flux from said light source; and

a light-guiding optical system, disposed in an optical path between said optical integrator and said surface to be irradiated, for guiding luminous fluxes from a number of light sources formed by said optical integrator to said surface to be irradiated.

7. An illumination optical apparatus according to claim 6, wherein said light-guiding optical system comprises:

a condenser optical system, disposed in the optical path between said optical integrator and said surface to be irradiated, for collecting luminous fluxes from a number of light sources formed by said optical integrator so as

to form an illumination field in a superimposing manner;

an image forming optical system, disposed in an optical path between said condenser optical system and said surface to be irradiated, for forming an image of said illumination field near said surface to be irradiated according to a luminous flux from said illumination field; and

an aperture stop, disposed in an optical path of said image forming optical system at a position substantially optically conjugate with a position where said number of light sources are formed, for blocking an unnecessary luminous flux.

8. An illumination optical system according to claim 6, wherein each said micro lens in said optical integrator has at least one refractive surface formed into an aspheric form which is symmetrical about an axis parallel to a reference optical axis in order to attain a substantially uniform illuminance on said surface to be irradiated.

9. An illumination optical system according to claim 8, wherein said optical integrator has a number of combining optical systems whose optical axes are respective axes parallel to said reference optical axis,

at least one refractive surface formed aspheric being formed into a predetermined aspheric surface in order to favorably restrain coma from occurring in said combining optical systems.

10. An illumination optical system according to

claim 8, wherein a filter having a predetermined optical transmissivity distribution is disposed near said optical integrator on the entrance side thereof in order to correct unevenness in illumination on said surface to be irradiated; and

wherein positioning means, connected to said optical integrator and said filter, for positioning said optical integrator and filter with respect to each other is provided.

11. An illumination optical system according to claim 8, wherein an iris stop adapted to change the size of an opening portion is disposed adjacent the exit surface of said optical integrator.

12. An illumination optical system according to claim 8, wherein said optical integrator has at least two optical element bundles disposed along said reference optical axis with a gap therebetween,

at least two of said optical element bundles having said aspheric optical surface.

13. An illumination optical system according to claim 12, wherein at least two of said optical element bundles have a number of combining optical systems each comprising at least two micro optical elements corresponding to each other along said axis, all optical surfaces in said combining optical systems being formed into aspheric surfaces having properties identical to each other.

14. An illumination optical system according to

claim 12, comprising positioning means, connected to at least two of said optical element bundles, for positioning at least two of said optical element bundles with respect to each other.

15. An illumination optical system according to claim 8, wherein said optical integrator has at least 1,000 axes.

16. An illumination optical system according to claim 6, having light source image enlarging means, disposed in the optical path between said optical integrator and said light source means at or near a position conjugate with said surface to be irradiated, for enlarging said light source image.

17. An illumination optical system according to claim 16, wherein a divergent angle of a luminous flux by way of said light source image enlarging means is determined such that no loss in illumination light occurs in said optical integrator.

18. An illumination optical system according to claim 17, wherein said optical integrator has a plurality of lens surfaces, arranged two-dimensionally, each forming said light source image;

wherein said light source image enlarging means enlarges said light source image formed by way of said lens surface; and

wherein said divergent angle of said light source image

enlarging means is set such that said enlarged light source image is smaller than said lens surface.

19. An illumination optical system according to claim 16, wherein said optical integrator has a plurality of lens surfaces, arranged two-dimensionally, each forming said light source image.

20. An illumination optical system according to claim 16, wherein a substantially uniform illuminance distribution is formed in a near field of said light source image enlarging means.

21. An illumination optical system according to claim 16, wherein only one pattern is formed in a far field of said light source image enlarging means.

22. An illumination optical system according to claim 16, wherein said far field pattern of said light source image enlarging means is circular, elliptical, or polygonal.

23. An illumination optical system according to claim 16, wherein, at a pupil of said illumination optical apparatus, a secondary light source having an optical intensity distribution in which the optical intensity in a pupil center region including an optical axis in a region on said pupil is set lower than that in a region surrounding said pupil center region is formed.

24. An illumination optical system according to claim 16, further comprising a diffraction optical element, disposed between said light source means and said optical

integrator, for controlling a form of said secondary light source formed at the pupil of said illumination optical apparatus.

25. An illumination optical system according to claim 24, having zero-order light blocking means, disposed between said diffraction optical element for controlling the form of said secondary light source and said optical integrator, for blocking zero-order light from said diffraction optical element for controlling the form of said secondary light source.

26. An illumination optical system according to claim 25, wherein said optical integrator comprises a plurality of lens surfaces arranged two-dimensionally and an entrance-side cover glass disposed on the entrance side of said plurality of lens surfaces,

said entrance-side cover glass being provided with said zero-order light blocking means.

27. An illumination optical system according to claim 16, wherein said light source image enlarging means has a diffraction optical element or diffuser.

28. An illumination optical system according to claim 27, wherein an antireflection film with respect to a wavelength of said illumination light is disposed on a surface of said diffraction optical element or diffuser.

29. An illumination optical system according to claim 16, wherein said optical integrator comprises a

plurality of lens surfaces arranged two-dimensionally and an exit-side cover glass disposed on the exit side of said plurality of lens surfaces,

said exit-side cover glass being provided with a light-shielding member for blocking light passing through a region different from said plurality of lens surfaces toward said surface to be irradiated.

30. An illumination optical system according to claim 16, comprising a micro fly's eye disposed in the optical path between said light source means and said surface to be irradiated, said micro fly's eye comprising a substrate having a surface formed with a plurality of lens surfaces,

said lens surfaces of said micro fly's eye being provided with an antireflection film with respect to said illumination light.

31. An illumination optical system according to claim 16, comprising illuminance distribution correcting means, disposed between said light source means and said optical integrator, for controlling respective intensity distributions of Fourier-transformed images of said plurality of light source images independently from each other.

32. An illumination optical system according to claim 31, wherein said optical integrator comprises a plurality of lens surfaces arranged two-dimensionally, an entrance-side cover glass disposed on the entrance side of

said plurality of lens surfaces, and an exit-side cover glass disposed on the exit side of said plurality of lens surfaces,

said illuminance distribution correcting means being disposed in an optical path between said entrance-side cover glass and said exit-side cover glass.

33. An illumination optical system according to claim 16, wherein said illumination optical apparatus forms an illumination area on said surface to be irradiated, said illuminance region having a form whose length in a predetermined direction differs from that in a direction orthogonal to said predetermined direction.

34. An illumination optical system according to claim 28, wherein said antireflection film has at least one ingredient selected from aluminum fluoride; barium fluoride; calcium fluoride; cerium fluoride; cesium fluoride; erbium fluoride; gadolinium fluoride; hafnium fluoride; lanthanum fluoride; lithium fluoride; magnesium fluoride; sodium fluoride; cryolite; chiolite; neodymium fluoride; lead fluoride; scandium fluoride; strontium fluoride; terbium fluoride; thorium fluoride; yttrium fluoride; ytterbium fluoride; samarium fluoride; dysprosium fluoride; praseodymium fluoride; europium fluoride; holmium fluoride; bismuth fluoride; a fluorine resin comprising at least one material selected from the group consisting of polytetrafluoroethylene, polychlorotrifluoroethylene, polyvinyl fluoride, fluorinated ethylene propylene resin,

polyvinylidene fluoride, and polyacetal; aluminum oxide; silicon oxide; germanium oxide; zirconium oxide; titanium oxide; tantalum oxide; niobium oxide; hafnium oxide; cerium oxide; magnesium oxide; neodymium oxide; gadolinium oxide; thorium oxide; yttrium oxide; scandium oxide; lanthanum oxide; praseodymium oxide; zinc oxide; lead oxide; a mixture group and complex compound group comprising at least two materials selected from a group of silicon oxides; a mixture group and complex compound group comprising at least two materials selected from a group of hafnium oxides; and a mixture group and complex compound group comprising at least two materials selected from a group of aluminum oxides.

35. An illumination optical system according to claim 16, wherein said light source means supplies illumination light having a wavelength of 200 nm or shorter.

36. An illumination optical system according to claim 35, wherein said diffraction optical element or said micro fly's eye has silica glass doped with fluorine.

37. An illumination optical apparatus for illuminating a surface to be irradiated with a luminous flux from a light source,

said apparatus including a plurality of optical elements disposed in an optical path between said light source and said surface to be irradiated,

at least one of said optical elements comprising positioning means, provided in said at least one optical

element, for optically positioning said at least one optical element.

38. An illumination optical system according to claim 37, wherein said positioning means is disposed outside the optical path between said light source and said surface to be irradiated.

39. An illumination optical apparatus for illuminating a surface to be irradiated with illumination light from a light source,

said apparatus comprising a micro fly's eye disposed in an optical path between said light source and said surface to be irradiated, said micro fly's eye having a substrate with a surface formed with a plurality of lens surfaces; and

a condenser optical system, disposed in an optical path between said micro fly's eye and said surface to be irradiated, for guiding a luminous flux from said micro fly's eye to said surface to be irradiated or a surface optically conjugate with said surface to be irradiated,

said lens surfaces of said micro fly's eye being provided with an antireflection film with respect to said illumination light.

40. An illumination optical apparatus for illuminating a surface to be irradiated with illumination light from a light source, said apparatus comprising:

a micro fly's eye disposed in an optical path between

said light source and the surface to be irradiated, said micro fly's eye having a substrate with a surface formed with a plurality of lens surfaces;

a condenser optical system, disposed in an optical path between said micro fly's eye and said surface to be irradiated, for guiding a luminous flux from said micro fly's eye to said surface to be irradiated or a surface optically conjugate with said surface to be irradiated; and

an exit-side protecting member disposed on the exit side of said micro fly's eye and formed from a material transparent to said illumination light,

said exit-side protecting member having a light-shielding member, provided in said exit-side protecting member, for blocking light passing through a region of said micro fly's eye different from said plurality of lens surfaces toward said surface to be irradiated.

41. An illumination optical apparatus according to claim 40, wherein said optical integrator comprises an entrance-side cover glass disposed on the entrance side of said micro fly's eye.

42. An illumination optical apparatus, adapted to be combined with an exposure apparatus comprising a projection optical system by which an image of a pattern on a mask disposed at a first surface is formed on a photosensitive substrate disposed at a second surface, for illuminating said first surface with a luminous flux from

a light source, said illumination optical apparatus comprising:

multiple luminous flux superimposing means, disposed between said light source and said first surface, for dividing said luminous flux from said light source and superimposing thus divided number of luminous fluxes on an illumination field which is a region on a predetermined surface; and

an illumination image forming optical system, disposed between said multiple luminous flux superimposing means and said first surface, for forming an image of said illumination field on or near said first surface,

said illumination image forming optical system having an aperture stop disposed at a position optically conjugate with a pupil of said projection optical system.

43. An exposure apparatus for projecting a pattern of a mask onto a photosensitive substrate,

said exposure apparatus comprising the illumination optical apparatus according to claim 6,

wherein said surface to be irradiated is set on said photosensitive substrate.

44. An exposure apparatus for transferring a pattern of a mask disposed on a first surface onto a work disposed on a second surface, said exposure apparatus comprising:

the illumination optical apparatus according to claim 8 for illuminating said first surface; and

a projection exposure apparatus, disposed in an optical

path between said first surface and said second surface, for projecting said pattern of mask onto said work;

said illumination optical apparatus further comprising optical intensity distribution changing means, disposed in the optical path between said light source and said optical integrator, for changing an optical intensity distribution of a luminous flux incident on said optical integrator.

45. An exposure apparatus illuminating a mask formed with a pattern with illumination light in a predetermined wavelength range so as to form an image of said pattern onto a substrate by way of a projection optical system,

said exposure apparatus comprising the illumination optical apparatus according to claim 16 for supplying said illumination light to said mask.

46. An exposure apparatus according to claim 45, wherein an illumination area on said mask has a form whose length in a predetermined direction differs from that in a direction orthogonal to said predetermined direction; and

wherein exposure is carried out while changing a relative relationship between said mask and said illumination area.

47. An exposure method in which a mask formed with a pattern is illuminated with illumination light in a predetermined wavelength range so as to form an image of said pattern onto a substrate by way of a projection optical

system,

wherein said illumination light is supplied to said mask by use of the illumination optical apparatus according to claim 16.

48. An observation apparatus for forming an image of an object to be observed, said apparatus comprising:

the illumination optical apparatus according to claim 6 for illuminating said object to be observed; and

an image forming optical system, disposed between said object to be observed and said image, for forming an image of said object to be observed according to light having traveled by way of said object to be observed.

49. An illumination optical apparatus for illuminating a surface to be irradiated with illumination light from a light source,

said illumination optical apparatus comprising an optical integrator, disposed in an optical path between said light source and said surface to be irradiated, for forming a secondary light source according to a luminous flux from said light source;

a condenser optical system, disposed between said optical integrator and said surface to be irradiated, for guiding a luminous flux from said optical integrator to said surface to be irradiated or a surface optically conjugate with said surface to be irradiated; and

a diffraction optical element disposed in an optical

path between said light source and said surface to be irradiated,

a surface of said diffraction optical element being provided with an antireflection film with respect to said illumination light.

50. An illumination optical system according to claim 49, wherein said antireflection film has at least one ingredient selected from aluminum fluoride; barium fluoride; calcium fluoride; cerium fluoride; cesium fluoride; erbium fluoride; gadolinium fluoride; hafnium fluoride; lanthanum fluoride; lithium fluoride; magnesium fluoride; sodium fluoride; cryolite; chiolite; neodymium fluoride; lead fluoride; scandium fluoride; strontium fluoride; terbium fluoride; thorium fluoride; yttrium fluoride; ytterbium fluoride; samarium fluoride; dysprosium fluoride; praseodymium fluoride; europium fluoride; holmium fluoride; bismuth fluoride; a fluorine resin comprising at least one material selected from the group consisting of polytetrafluoroethylene, polychlorotrifluoroethylene, polyvinyl fluoride, fluorinated ethylene propylene resin, polyvinylidene fluoride, and polyacetal; aluminum oxide; silicon oxide; germanium oxide; zirconium oxide; titanium oxide; tantalum oxide; niobium oxide; hafnium oxide; cerium oxide; magnesium oxide; neodymium oxide; gadolinium oxide; thorium oxide; yttrium oxide; scandium oxide; lanthanum oxide; praseodymium oxide; zinc oxide; lead oxide; a mixture

group and complex compound group comprising at least two materials selected from a group of silicon oxides; a mixture group and complex compound group comprising at least two materials selected from a group of hafnium oxides; and a mixture group and complex compound group comprising at least two materials selected from a group of aluminum oxides.

51. An illumination optical system according to claim 39, wherein said antireflection film has at least one ingredient selected from aluminum fluoride; barium fluoride; calcium fluoride; cerium fluoride; cesium fluoride; erbium fluoride; gadolinium fluoride; hafnium fluoride; lanthanum fluoride; lithium fluoride; magnesium fluoride; sodium fluoride; cryolite; chiolite; neodymium fluoride; lead fluoride; scandium fluoride; strontium fluoride; terbium fluoride; thorium fluoride; yttrium fluoride; ytterbium fluoride; samarium fluoride; dysprosium fluoride; praseodymium fluoride; europium fluoride; holmium fluoride; bismuth fluoride; a fluorine resin comprising at least one material selected from the group consisting of polytetrafluoroethylene, polychlorotrifluoroethylene, polyvinyl fluoride, fluorinated ethylene propylene resin, polyvinylidene fluoride, and polyacetal; aluminum oxide; silicon oxide; germanium oxide; zirconium oxide; titanium oxide; tantalum oxide; niobium oxide; hafnium oxide; cerium oxide; magnesium oxide; neodymium oxide; gadolinium oxide; thorium oxide; yttrium oxide; scandium oxide; lanthanum

oxide; praseodymium oxide; zinc oxide; lead oxide; a mixture group and complex compound group comprising at least two materials selected from a group of silicon oxides; a mixture group and complex compound group comprising at least two materials selected from a group of hafnium oxides; and a mixture group and complex compound group comprising at least two materials selected from a group of aluminum oxides.

52. An illumination optical apparatus according to claim 42, wherein said multiple luminous flux superimposing means divides a wavefront of said luminous flux from said light source.

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